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Review

Does sandblasting improve bond strength in resin composite repair?

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ABSTRACT

There are many studies investigating the application of air abrasion as a surface treatment for resin-based composite (RBC) repair, some with conflicting results, which makes it difficult for the dentist to know whether to use it or not. The aim of this study is to produce an integrative literature review to identify the scientific evidence on the use of air abrasion for repairing direct RBC restorations. A PICO question was elaborated to guide the selection of literature in a database following the PRISMA statement. The keywords used in Medical Literature Analysis and Retrieval System Online (PubMed) and Service Scopus (SCOPUS) were "composite resin*" AND "air abrasion" OR sandblasting AND repair* OR "composite repair". In Web of Science (WoS), the search strategy was "composite resins" AND "air abrasion" OR sandblasting AND "composite repair". Papers published in peer-reviewed journals since 2010, in English, and related to the aim of this study were the goal of this search. After applying inclusion and exclusion criteria to titles, abstracts, and full text, forty-nine scientific papers were selected for this study. This literature review focused on *in vitro* studies evaluating bond strength. The most common methodology found in the literature to evaluate bond strength in composite repair were shear and microshear bond strength tests (23 studies), as well as tensile and microtensile bond strength tests (24 studies). Several studies evidence air abrasion as an efficient mechanical surface treatment for composite repair, leading to a greater bond strength when compared to no preparation, diamond bur preparation alone, or distinct types of lasers.

Introduction

Air abrasion, also known as sandblasting, was created in 1945 with the intention of reducing pain and discomfort during caries excavation [1]. However, it was hardly used in dental clinical practice because it could not produce the well-defined walls and angles needed for self-retentive amalgam and direct gold-foil restorations. After the development of adhesive dentistry, a minimally invasive philosophy of intervention emerged in dental practice, and air abrasion became a valuable tool along with the dentist's clinical equipment [2].

Devices designed for air abrasion generate a high-speed flow of aluminum oxide particles that hit tooth structures and dental materials. The impact of these alumina particles results in a rough surface [3]. The efficiency of this process depends on the target structure's mechanical properties and the device's operational adjustments, such as air pressure, particle size and hardness, angle of application, distance from the target, and time [2].

Benefits of the use of air abrasion in dentistry are found in the literature, such as conservative cavity preparation in enamel, cleaning prepared cavities prior to dental bonding, and roughening intaglio surfaces of metallic and ceramic restoration prior to cementation procedures [2]. Another advantage reported is its ability to improve retention in resin-based composite (RBC) repair [4,5]. Adhesive restorative dentistry permits the repair of RBC direct restorations presenting small defects instead of replacing them completely. This approach enhances the restoration's long-term survival in the oral cavity and breaks the restorative cycle of death, which leads to a higher preservation of the remaining tooth structure [6,7].

In a new RBC restoration, each increment applied to the filling is bonded to the previous one by its reaction to an unpolymerized oxygen-inhibit thin layer lying over this last increment after photocuring. This reaction produces a chemical bond between both increments, resulting

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in a homogenous bulk restoration [8]. When the dentist is dealing with the repair of aged RBC restorations, the old organic polymeric matrix does not bond to the monomers in the new RBC. In these situations, all monomers from the old RBC are either part of the polymeric chain or have been released to the oral environment. This repair might result in a low-strength restoration, mainly because the bond interface between the old material and the new one is not as resistant as the core material itself [7]. Thus, the old restoration demands a surface treatment, either chemical and/or mechanical, to achieve good retention to the new material [7]. These surface treatment methods may include diamond burs and/or air abrasion, associated or not with acid etching/cleaning and silane/MDP [9,10]. The combination of chemical and mechanical treatments is important to produce a high-quality repair interface [6].

Regarding chemical treatments, the dentist may use etching with phosphoric or hydrofluoric acid, as well as silane and/or adhesive application. Air abrasion and diamond burs are considered mechanical methods to produce roughness on the restoration surface [11]. The use of air abrasion for this purpose presents some advantages, such as reduced heat, vibration, and noise, which makes the procedure more comfortable for the patient [2]. As a disadvantage, one can find an accumulation of powder in the operatory field when waterless air abrasion is used [12]. Though there are many studies investigating its application, they present conflicting results, which makes it difficult for the dentist to know whether to use chemical treatments or not.

There are different methods used to investigate bond strength in RBC repair, and the most frequently used are the (micro)shear bond strength and the (micro)tensile bond strength tests [13,14]. The first one uses a loop wire or a notched-edge blade in a universal testing machine positioned at the level of the bonding interface, applying lateral sliding forces until failure. This is an easy and fast method to evaluate bond strength, and no additional procedures are needed at the sample after the bonding protocol [13,15].

The microtensile bond strength test also uses the same machine; however, beams of approximately one mm^2 are produced as samples, and a pulling force is applied until failure. Multiple samples might be produced from a single tooth. This method produces a more precise measurement of the tension needed to start the bonding rupture since the tensile distribution along the beam is more uniform [13,16]. The results of both tests are presented in megapascals.

Hence, the aim of this study is to produce an integrative literature review to identify the scientific evidence for the use of air abrasion in repairing direct RBC restorations.

Methods

This is an integrative review of literature that followed a track workflow starting with theme delimitation and building a PICO question; analysis and selection of literature found in the data-base; data extraction from included papers; analysis and discussion of data; and acquisition of an answer to the research question, "Does air abrasion improve bond strength in RBC repair?", according to the PRISMA statement (Fig. 1). The PICO question stated the effectiveness of air abrasion (I/C) on the enhancement of the bond quality (O) of RBC repair (P). The keywords used in Medical Literature Analysis and Retrieval System Online (PubMed) and Service Scopus (SCOPUS) were "composite resin*" AND "air abrasion" OR sandblasting AND repair* OR "composite repair". In Web of Science (WoS), "composite resins" AND "air abrasion" OR sandblasting AND "composite repair" (Table 1).

In each database's search portal, the advanced search tool was used to add the terms in the query box, between February and March 2023. It was included in this study all research papers published in peer-reviewed journals published in English since 2010. Research papers were included if they evaluated air abrasion influence in RBC repair. It was excluded from the selection all papers not related to the research question, the research theme, or papers not comparing air abrasion with other surface treatments on RBC repair. Books, editorials, theses,

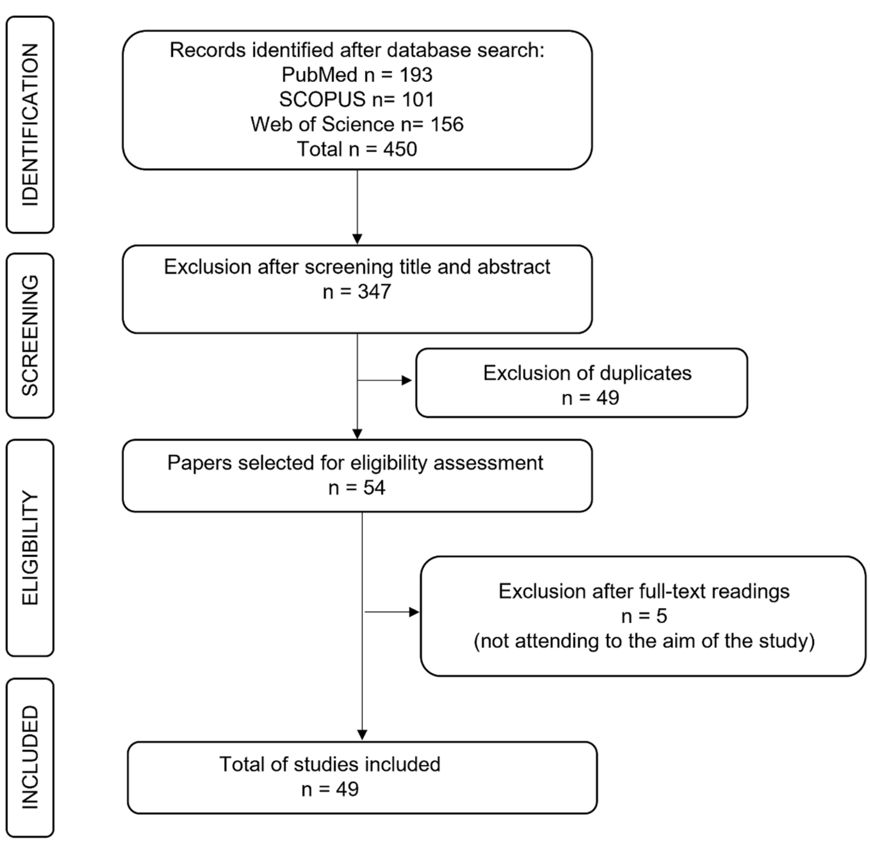

Fig. 1. Literature search and selection workflow following PRISMA statement.

Table 1
Search strategy.

Database	Search strategy	Found papers
PubMed February and March 2023	(((("composite resin") AND ("air abrasion")) OR (sandblasting)) AND (repair)) OR ("composite repair")	193
Scopus February and March 2023	(("composite resin") AND ("air abrasion")) OR (sandblasting)) AND (repair)) OR ("composite repair"))	151
WoS February and March 2023	(("composite resins") AND ("air abrasion") OR (sandblasting)) AND ("composite repair"))	156

comments, case reports, book chapters, or duplicated papers were also excluded. Two independent researchers (RZ, ARM) performed the search and literature analysis. When there was disagreement regarding any paper analysis, a third researcher was consulted (GAA).

Studies were selected by applying inclusion and exclusion criteria to titles, abstracts, and full texts. Once all papers were selected, the data was extracted and merged into one table, which is presented in the next chapter.

Results

Data compilation from studies included in the literature review are presented in Table 2. Forty-nine scientific papers were selected for this study from 2010 to 2022, published in peer-reviewed journals. All papers were *in vitro* studies investigating the influence of air abrasion on the bond strength of RBC repair and comparing this technique to other surface treatments described in the literature. Among the methods used to evaluate the efficiency of different surface treatments, one can identify scanning electron microscope (SEM) evaluation (2 studies), surface roughness analysis (Ra) test (5 studies), shear and microshear bond strength tests (23 studies), as well as tensile and microtensile bond strength tests (24 studies). Only one study used interfacial fracture toughness as a method for evaluating RBC repair [17].

Discussion

Although both (micro)shear and (micro)tenisle bond strength tests are reliable methods to investigate adhesive protocols in dentistry, their data results are different. This difference is due to the vectorial directions of forces applied during the test: a sliding approach on (micro) shear and a pulling approach in (micro)tenisle. Therefore, one cannot compare data from these test methods to each other, and this is why this literature review presents a separate discussion of evidence according to the method used to test the RBC bond strength.

Silica-coated aluminum oxide sandblast (CoJet) particles' size is 27 µm, while Al_2O_3 particles' size varies from 30 to 50 µm. CoJet has spherical shaped particles, while Al_2O_3 has sharp-edged ones. SEM evaluations reported a lower extent of irregularities produced by CoJet when compared to Al_2O_3 sandblasting, probably due to the difference in particle shape. Both sands are composed of Al_2O_3, but CoJet has the particles coated with silica. The theoretical justification for this particle modification is that sandblasting using silica-coated alumina particles would produce a "cold silicatization" of the ceramic surface. However, neither the shape difference nor the chemical interaction of CoJet with ceramic substrates presented a significant improvement in cement bonding strength to ceramic compared to Al_2O_3 sandblasting. Most papers do not describe such details about the differences between CoJet and Al_2O_3 sandblasting, and even when they do investigate it, no difference in the outcomes is observed [18,19].

Considering shear and microshear tests, some authors [9,11,20–25] identified that both CoJet and Al_2O_3 air abrasion techniques, followed by adhesive application, produced higher bond strength values

Table 2
Data compilation from studies included in the literature review.

Author/Year	Surface treatment	Outcome investigated	Mains results
Costa et al. (2010)	Control group with no treatment // diamond burs // Al_2O_3 air abrasion. All treatments were followed by hydrophobic/ hydrophilic adhesive system.	µTBS, Ra and SEM	Air abrasion presented higher values of bond strength regardless of adhesive hydrophily.
Kimyai et al. (2010)	Control group with no treatment; diamond burs, Al_2O_3 air abrasion, Erbium Laser. Silane and bonding agent (Single Bond) were used in all groups.	SBS	Surface treatment presented higher values than control group. Among experimental groups, air abrasion had the best outcome.
Loomans et al. (2011)	- Control group with no treatment // diamond bur - 50 µm Al_2O_3 air abrasion / 30 µm CoJet air abrasion - 37 % phosphoric acid // 3 % HydroFluoric acid for 20 s / 120 s // - 9,6 % HydroFluoric acid for 20 s / 120 s	µTBS	Air abrasion was the surface treatment that presented the best results on overall evaluation.
Melo et al. (2011)	- Control group with no treatment - phosphoric acid, silane, adhesive // phosphoric acid, adhesive - diamond bur, 37 % phosphoric acid, silane, adhesive // diamond bur, 37 % phosphoric acid, adhesive - Airabrasion(50 µmAl_2O_3),phosphoric acid, silane, adhesive// Air abrasion (50 µm Al_2O_3), phosphoric acid, adhesive	SBS	Composite surface treated with diamond burs or air abrasion presented similar SBS. Composite repair using phosphoric acid and adhesive alone should not be used, once it was effective only in new restorations. Silane did not present significant effect on SBS values.
Costa et al. (2012)	- No treatment + hydrophobic adhesive // Fine-grit + hydrophobic adhesive - Medium-grit + hydrophobic adhesive // Coarse-grit + hydrophobic adhesive - 50 µm Al_2O_3 air abrasion + hydrophobic adhesive - No treatment + hydrophilic adhesive // Fine-grit + hydrophilic adhesive - Medium-grit + hydrophilic adhesive // Coarse-grit + hydrophilic adhesive - 50 µm Al_2O_3 air abrasion + hydrophilic adhesive	µTBS, SNU, Ra and SA	The Al_2O_3 air abrasion treatment provides the highest composite repair strength likely due to the high SA produced. The bonding agent did not seem to affect the RS strength after 6 months, although early signs of degradation were detected for the hydrophilic system.

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Table 2 (*continued*)

Author/Year	Surface treatment	Outcome investigated	Mains results
Cho et al. (2013)	- Control group with no treatment // diamond bur - 50 µm Al_2O_3 Air abrasion / 30 µm CoJet air abrasion - 37 % phosphoric acid for 15 s // Erbium Laser	SBS	50 µm Al_2O_3 air abrasion or 30 µm CoJet Air abrasion followed by adhesive bond system produced higher SBS values than other surface treatments tested.
Özcan et al. (2013)	- 30 µm CoJet air abrasion, silane, and adhesive - Adhesive Only	µTBS	Both treatments presented similar results.
Celik et al. (2014)	- Diamond bur - 50 µm Al_2O_3 air abrasion - Both groups were followed by different adhesive systems application	µTBS	Air abrasion produced higher values of bond strength.
Eliasson et al. (2014)	- Control group with no treatment // 30 µm CoJet air abrasion // Silane coating All groups were subdivided according to the adhesive system used: 1-step-selfetch; 2-step-self-etch; 3-step-etch'nrinse	µTBS	Silanized groups presented better results
Hemadri et al. (2014)	- No treatment + Clearfil repair // No treatment + All-bond 2 adhesive systems - Diamond bur + Clearfil repair // Diamond bur + All-bond 2 adhesive systems - 50 µm Al_2O_3 air abrasion + Clearfil repair - 50 µm Al_2O_3 air abrasion + All-bond 2 adhesive systems	SBS	Air-abrasion of aged composite substrate followed by application of Clearfil repair adhesive system yielded the highest repair bond strength than the any other combinations tested in the present study.
Baena et al. (2015)	- negative controle (adhesive) // diamond bur + adhesive - 27 µm Al_2O_3 air abrasion + adhesive // 30 µm CoJet + silane + adhesive	µTBS	Increase in roughness by any means tested in this study produced enhancement of composite repair bond strength
Barcellos et al. (2015)	- Prime&bond 2.1 - Al_2O_3 air abrasion and Prime&bond 2.1 // Erbium Laser and Prime&bond 2.1 - 9,6 % HydroFluoric acid for 120 s and silane // Silane alone - acrylic resin monomer and universal bond system // self-etch bond system	TBS	Use of air abrasion or diamond bur before Prime&bond 2.1 produced better results of bond strength.
Batista et al. (2015)	- Control group with no treatment // diamond bur - 50 µm Al_2O_3 air abrasion / silica-modified Al_2O_3 air abrasion	TBS and Ra	silica-modified Al_2O_3 air abrasion was the only surface treatment to enhance bond strength
Nassoohi et al. (2015)	- Erbium laser / Neodymium laser - diamond bur + phosphoric acid - 50 µm Al_2O_3 air abrasion + phosphoric acid - HydroFluoric acid + silane	µTBS	compared to control group Al_2O_3 air abrasion + phosphoric acid can produce higher values of bond strength
Ahmadizenouz et al. (2016)	- Control group with no treatment - 50 µm Al_2O_3 air abrasion // Laser Er:YAG - diamond bur + phosphoric acid // 9 % hydrofluoric acid for 120 s	SBS	All experimental groups promoted high bond strength values compared to the control group. There was no difference among the surface treatments itself, but diamond bur showed higher values of SBS.
Karaarslan et al. (2016)	- Phosphoric acid - Er:YAG laser - 50 µm Al_2O_3 air abrasion	µTBS	The treatment with air abrasion was more effective than the other treatments, and thus, it is suggested for repairing composites.
Wendler et al. (2016)	- Negative reference (diamond bur – red code) - Etching with 35 % phosphoric acid // Diamond bur (blue code) - 30 µm CoJet air abrasion // Silane // 30 µm CoJet air abrasion + silane - Syntac primer // Syntac adhesive - Heliobond // Syntac primer + adhesive + Heliobond - Positive reference (No surface treatment, no aging after repair) - Positive reference (No surface treatment. After repair, aged in distilled water for 30 days)	TBS	No significant differences in TBS were observed among the mechanical surface treatments, despite variations in surface roughness profiles. Phosphoric acid etching significantly improved repair bond strength values. The cohesive TBS of the material was only reached using resin bonding agents. Application of an intermediate bonding system plays a key role in achieving reliable repair bond strengths, whereas the kind of mechanical surface treatment appears to play

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Table 2 (*continued*)

Author/Year	Surface treatment	Outcome investigated	Mains results
			a secondary role.
Andrade et al. (2017)	- Control group with no treatment // 50 µm Al_2O_3 air abrasion // Silane - total etch adhesive system // 1-step self-etch adhesive system // 2-step self-etch adhesive system // air abrasion + total etch adhesive // air abrasion and 1-step self-etch adhesive - 50 µm Al_2O_3 air abrasion and 2-step self-etch adhesive // Silane and total etch adhesive // Silane and 1-step self-etch adhesive // Silane and 2-step self-etch adhesive system	µSBS	All surface treatments were able to enhance the bond strength. Self-etch adhesive were more efficient when no pre-treatment was preformed. The greatest SBS values was obtained by association of air abrasion and 2-step self-etch adhesive.
Al-Asmar et al (2017)	- diamond bur and 37 % phosphoric acid // diamond bur, hydrofluoric acid and silane - 50 µm Al_2O_3 air abrasion + 37 % phosphoric acid - 50 µm Al_2O_3 air abrasion + 37 % phosphoric acid + silane - 50 µm Al_2O_3 air abrasion + hydrofluoric acid + silane	SBS	The best SBS was obtained by 50 µm Al_2O_3 air abrasion, hydrofluoric acid and silane group.
Atalay et al. (2017)	- No treatment - Single Bond Universal (self-etch mode) - 37 % phosphoric acid + Single Bond Universal - Er,Cr:YSGG laser + 37 % phosphoric acid + Single Bond Universal - 50 µm Al_2O_3 air abrasion + 37 % phosphoric acid + Single Bond Universal	µTBS	Surface treatment with an Er,Cr:YSGG laser caused higher repair bond strength values but they were not different from those of the Al_2O_3 sandblasting group. In clinical conditions the requirement of rubber-dam application during sandblasting might make lasers preferable due their ease of use without causing any vibration, pressure, or pain in the patients.
Brum et al. (2017)	- Control group with no treatment // 50 µm Al_2O_3 air abrasion - liquid acetone // gel acetone - liquid alcohol // gel alcohol	µSBS	Air abrasion surface treatment produced superior bond strength for composite repair.
Fornazari et al. (2017)	- hydrophobic adhesive // Silane and hydrophobic adhesive // Silane + MDP and hydrophobic adhesive // universal adhesive system // Silane and universal adhesive system - Silane + MDP and universal adhesive system *All groups were previously treated by two different protocols: with air abrasion + phosphoric acid etching and without air abrasion nor etching	µSBS	Adding MDP to silane did not promote any statical difference on bond strength. Air abrasion enhanced bond strength. Use of phosphoric acid etching + silane prior to adhesive application helped the increase in µSBS values.
Souza et al. (2017)	- Control group with no treatment - 50 µm Al_2O_3 air abrasion // 50 µm Al_2O_3 air abrasion and adhesive - 50 µm Al_2O_3 air abrasion + silane and adhesive	µTBS	Control group presented lower values of bond strength in both times. Aging influenced bond strength, and 50 µm Al_2O_3 air abrasion + silane and adhesive presented the best results.
Altinci et al. (2018)	- Control group with no treatment - 320-grit surface roughening - 320-grit + universal adhesive // 320-grit + silane + universal adhesive - 320-grit + CoJet + silane + universal adhesive	µSBS	Use of silane and air abrasion promotes higher bond strength in composite repair.
Ayres et al. (2019)	- 50 µm Al_2O_3 air abrasion + silane + hydrophobic bonding resin - 50 µm Al_2O_3 air abrasion + plasma treatment + silane + hydrophobic bonding resin - 50 µm Al_2O_3 air abrasion + silane + plasma treatment + hydrophobic bonding resin - Plasma treatment + silane + hydrophobic bonding resin - Plasma treatment + silane // Plasma treatment + hydrophobic bonding resin - Silane + plasma treatment + hydrophobic bonding resin // Silane + plasma treatment // Plasma treatment	SBS	Air abrasion + silane + hydrophobic adhesive was considered gold standard by the author for composite repair. In this study, this protocol presented significant higher results.
Eren et al. (2019)	- Control group with no treatment - diamond bur with and without silane - 50 µm Al_2O_3 air abrasion // 50 µm Al_2O_3 air abrasion and silane	SBS	Laser produced the lowest bond strength values, while diamond burs and air abrasion presented the best results.

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Table 2 (*continued*)

Author/Year	Surface treatment	Outcome investigated	Mains results
	- 30 μm CoJet air abrasion // erbium laser with and without silane		
Kanzow et al. (2019)	- control group with no treatment // diamond bur - 50 μm Al_2O_3 air abrasion // silica coated air abrasion. - Followed by application of: - conventional adhesive system // universal adhesive with silane	SBS	Air abrasion or silica coating presented the highest SBS values, regardless of the adhesive system used. Universal adhesives presented higher values than conventional ones when used without air abrasion.
Martos et al. (2019)	- Control group with no treatment - Gluma Self Etch adhesive system // Tokuyama Bond Force II adhesive system - 50 μm Al_2O_3 air abrasion and Gluma Sefl Etch - 50 μm Al_2O_3 air abrasion and Tokuyama Bond Force II	SBS	Using air abrasion along with Tokuyama Bond Force II produced the highest shear bond strength compared to other surface treatments tested.
Sismanoglu, (2019)	- Control group with no treatment // universal adhesive system - 37 % phosphoric acid + universal adhesive - 9 % hydrofluoric acid for 20s + universal adhesive - 50 μmAl_2O_3 air abrasion +universal adhesive// 30μmCoJet air abrasion +universal adhesive	μTBS and Ra	Air abrasion (CoJet or Al_2O_3) promoted higher Ra compared to other treatments, as well as higher bond strength
Aquino et al. (2020)	- Control group with no treatment // adhesive system - diamond bur and adhesive system // diamond bur, silane and and adhesive system - 50 μmAl_2O_3 air abrasion and adhesive // 50 μm Al_2O_3 air abrasion, silane and adhesive	μTBS	Air abrasion presented results of bond strength in composite repair similar to bulk composite cohesive strength. When diamond bur was used, lowest values were obtained compared to air abrasion. The use of silane associated to diamond burs increase its results.

Dieckmann et al. (2020)	- Negative control // Positive control
	- 46 μm diamond bur + silane (aged resin) // 46 μm diamond bur +silane +50 μm Al_2O_3 air abrasion (aged resin)
	- 100 μm diamond bur + silane (aged resin) // 100 μm diamond bur +silane +50 μm Al_2O_3 air abrasion (aged resin)
	- 46 μm diamond bur + silane // 46 μm diamond bur + silane + 50 μm Al_2O_3 air abrasion
	- 100 μm diamond bur + silane // 100 μm diamond bur + silane + 50 μm Al_2O_3 air abrasion
		μTBS	The age of the repaired composite has a major impact on the composite-composite bond strength, with lower repair bond strengths being achieved for aged than for immediately repaired composite. Aluminum oxide sandblasting and bur abrasion, irrespective of diamond bur grit size, seem to be equally effective as mechanical surface pretreatments for the repair of both aged and recently placed composite restorations.

Michelotti et al. (2020)	- Positive control // Diamond bur + Single Bond Universal // Diamond bur + Silane + Single Bond Universal - Diamond bur + Silane + Optibond FL // Diamond bur - 50 μm Al_2O_3 air abrasion + Single Bond Universal // 50 μm Al_2O_3 air abrasion + Silane + Single Bond Universal - 50 μm Al_2O_3 air abrasion + Silane + Optibond FL // 50 μm Al_2O_3 air abrasion - Silica coating + Single Bond Universal // Silica coating + Silane + Single Bond Universal - Silica coating + Silane + Optibond FL // Silica coating	μTBS	For composite repairs, the silane-containing universal adhesive can thus be used without a separate silanization step. Furthermore, after sandblasting the composite substrates with silica-coated aluminum oxide, the universal adhesive attained similar repair bond strength values as the conventional adhesive system. The combination of mechanical pretreatment and subsequent adhesive conditioning is crucial for adequate composite repairs.
Moura et al. (2020)	- Filtek Z350 composite // CAD/CAM nanoceramic composite Surface Treatments: - 30 μm CoJet air abrasion // 50 μm Al_2O_3 air abrasion // universal adhesive system	SBS	Air abrasion (CoJet or Al_2O_3) are the most effective methods to produce high quality repair to nanoceramic CAD/CAM composite.
Puleio et al. (2020)	- No surface treatment. - Etching for 30 s. // Etching for 60 s. - Diamond bur. // Diamond bur and etching for 30 s. //	Ra and SEM	Sandblasting is the best treatment to increase the surface roughness of a

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Table 2 (*continued*)

Author/Year	Surface treatment	Outcome investigated	Mains results
	Diamond bur and etching for 60 s. - 50 μm Al_2O_3 air abrasion // 50 μm Al_2O_3 air abrasion + etching for 30 s. - 50 μm Al_2O_3 air abrasion + etching for 60 s.		supra-nano composite.
Ritter et al. (2020)	- universal adhesive system - 50 μm Al_2O_3 air abrasion // 30 μm CoJet air abrasion	Interfacial fracture toughness	CoJet treatment produced the best fracture toughness of nanofilled composite.
Valizadeh et al. (2020)	- Diamond bur - x' laser - 50 μm Al_2O_3 air abrasion - Atmospheric plasma jet	μSBS	Surface treatment of composite resin by sandblasting, roughening by bur, laser irradiation, and aging had no significant effect on μSBS of repair composite; however, application of cold plasma spray after aging slightly increased the μSBS of repair composite.
Yarmohammadi, Farshchian (2020)	- No surface treatment (control group) - 50 μm Al_2O_3 air abrasion // Diamond bur - Hydrofluoric acid // Hydrofluoric acid + ultrasonic silicification	SBS	Etching with hydrofluoric acid and silanization could have superior effects in increasing shear bond strength between aged and new composite resins, which could be a suitable repair protocol to obtain optimal repair bond strength.
Akgül et al. (2021)	Control group with no treatment // 30 μm CoJet air abrasion // 50 μm Al_2O_3 air abrasion All groups were associated to no adhesive, total etch or self-etch systems.	SBS	Both air abrasion protocols produced enhanced bond strength values.
Benzi et al. (2021)	- No treatment - 50 μm Al_2O_3 air abrasion - Diamond bur	μTBS	The bulk fill resin composite tested present better repair performance when the same composite was used and sandblasting, or bur abrasion was performed. Conventional resin composite repair was less influenced by the material type and the surface treatment performed.
Burrer et al. (2021)	- 50 μm Al_2O_3 air abrasion + silane	μTBS	Bond strength of composite repair was enhanced by air abrasion regardless of the distance of application.
Dursun et al. (2021)	- control group with no treatment - Erbium laser // 50 μm Al_2O_3 air abrasion - Silicon polishing point	μTBS	Considering aging, air abrasion produced the higher values of bond strength
Kusdemir et al. (2021)	- 50 μm Al_2O_3 air abrasion + All Bond Universal // 50 μm Al_2O_3 air abrasion + Monobond Plus - 50 μm Al_2O_3 air abrasion + G-Premio Bond // 50 μm Al_2O_3 air abrasion + Gluma Bond Universal - 50 μm Al_2O_3 air abrasion + Clearfil Universal Bond // 50 μm Al_2O_3 air abrasion + Clearfil Universal Bond Quick - All Bond Universal // Monobond Plus // G-Premio Bond // Gluma Bond Universal - Clearfil Universal Bond // Clearfil Universal Bond Quick	SBS	Physical surface conditioning using Al_2O_3 air-abrasion enhanced the composite-composite adhesion in repair procedures. 10-MPD and silane containing universal adhesive systems increased the composite-composite adhesion. Air abrasion followed by silane or primer application appears to be essential to achieve the durable composite repair.
Negreiros et al. (2021)	- Control group with no treatment // 50 μmAl_2O_3 air abrasion+ silane+ adhesive - hydrophobic adhesive - Atmospheric plasma pressure (APP) jet and hydrophobic adhesive - Al_2O_3 air abrasion + hydrophobic adhesive // Al_2O_3 air abrasion, (APP) jet + hydrophobic adhesive // (APP) jet	SBS	Composite repair protocol could be simplified by using any roughness method on the surface prior to hydrophobic adhesive application.
Hashim, Abd-alla (2022)	- Diamond bur // Diamond bur + universal adhesive - Diamond bur + silane + universal adhesive - 50 μm Al_2O_3 air abrasion // 50 μm Al_2O_3 air abrasion + universal adhesive - 50 μm Al_2O_3 air abrasion + silane + universal adhesive	SBS	The sandblasted specimens presented with higher repair SBS values than those that underwent diamond bur abrasion. However, no difference in the SBS was

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Table 2 (*continued*)

Author/Year	Surface treatment	Outcome investigated	Mains results
			observed in both these treatment groups after the application of the Scotchbond Universal Adhesive. Furthermore, performing an additional silanizing step before applying the examined universal adhesive did not enhance the SBS of the repaired Filtek One Bulk Fill composite.
Karabekiroglu et al. (2022)	- AllBond Universal // ClerafilUniversal Bond Quick // Monobond Plus // G-Premio Bond // ClearfilUniversal Bond - 30 µm CoJet air abrasion + All Bond Universal - 30 µm CoJet air abrasion + Clerafil Universal Bond Quick // 30 µm CoJet air abrasion + Monobond Plus - 30 µm CoJet air abrasion + G-Premio Bond // 30 µm CoJet air abrasion + Clearfil Universal Bond	SBS	Silica-coating did not increase the bond strength for all adhesion promoters tested when immediate resin composite repair was performed. For the repair of resin composite, silane primers can be used effectively, but silica-coating particularly enhanced the adhesion to aged substrates.
Negreiros et al. (2022)	- 50 µm Al_2O_3 air abrasion + silane + hydrophobic bonding resin - 50 µm Al_2O_3 air abrasion + plasma treatment + silane + hydrophobic bonding resin - 50 µm Al_2O_3 air abrasion + silane + plasma treatment + hydrophobic bonding resin - Plasma treatment + silane + hydrophobic bonding resin - Plasma treatment + silane // Plasma treatment + hydrophobic bonding resin - plasma treatment + Silane + hydrophobic bonding resin // plasma treatment +Silane // Plasma treatment	SBS	Resin plasma treatment in combination with other surface treatments can improve the SBS of composite repairs after one year of water storage. The SBS of the composite repair was not stable over time regardless of the surface treatment.
Rashidi et al. (2022)	- 50 µm Al_2O_3 air abrasion + 37 % phosphoric acid + primer + Clearfil SE Bond - 50 µm Al_2O_3 air abrasion + 37 % phosphoric acid + primer + All-Bond Universal - diamond bur + 37 % phosphoric acid + primer + Clearfil SE Bond - diamond bur + 37 % phosphoric acid + primer + All-Bond Universal - Er:YAG laser + 37 % phosphoric acid + primer + Clearfil SE Bond - Er:YAG laser + 37 % phosphoric acid + primer + All-Bond Universal - 37 % phosphoric acid + primer + Clearfil SE Bond (control) // 37 % phosphoric acid + primer + All-Bond Universal (control)	µTBS	All surface treatments created acceptable bond strength. The surface treatment of the aged composite by the Er:YAG laser or air-abrasion along with the application of silane and All-Bond Universal provide high bond strength.
Ugurlu et al. (2022)	- 50 µm Al_2O_3 air abrasion // 50 µm Al_2O_3 air abrasion + silane - Diamond bur // Diamond bur + silane - Silane // No treatment	µTBS	The air-abrasion and bur roughening improved the repair bond strength ($p < 0.05$). The mechanical roughening treatments are necessary for the repair of resin composite. The universal adhesives might be used for the repair of resin composites regardless of silane content without prior silane application.

Yilmaz et al. (2022)	- air abrasion + Scotchbond Universal (SBU) // air abrasion+silane+ (SBU) // hydrofluoric acid + (SBU)
	- hydrofluoric acid+silane+(SBU) // air abrasion+hydrofluoric acid+silane+ (SBU)
	- silane + (SBU) // (SBU) // - air abrasion+G-Premio Bond // air abrasion+silane+G-Premio Bond
	- hydrofluoric acid+G-Premio Bond // hydrofluoric acid + silane+G-Premio Bond
	- air abrasion + hydrofluoric acid + silane+G-Premio Bond
		µTBS	In Scotchbond Universal and G-Premio Bond, the mean micro-tensile bond strength value of the no surface treatment subgroup was significantly lower than that of the positive control. While Scotchbond Universal and G-Premio Bond required mechanical roughening before adhesive application, Peak Universal Bond did not

(*continued on next page*)

Table 2 (*continued*)

Author/Year	Surface treatment	Outcome investigated	Mains results
	// silane+G-Premio Bond // G-Premio Bond - air abrasion+Peak Universal Bond // air abrasion+silane+Peak Universal Bond - hydrofluoric acid+Peak Universal Bond // hydrofluoric acid + silane+ Peak Universal Bond - air abrasion + hydrofluoric acid + silane+Peak Universal Bond // silane+Peak Universal Bond - Peak Universal Bond		require any surface treatment.

Footnotes: Al_2O_3: aluminum oxide; µm: micrometer; Er:YAG: Erbium Yag; Er,Cr: YSGG: Erbium, chromium-doped:yttrium-scandium-gallium-garnet; MDP: Methacryloyloxydecyl dihydrogen phosphate; APP: Atmospheric plasma pressure; µTBS: microtensile bond strength; Ra: Roughness; SEM: Scanning electron microscopy; SBS: Shear bond strength; SNU: Silver nitrate uptake; SA: Estimation of surface area; TBS: Tensile Bond Strength; µSBS: Microshear bond strength; mm: millimeters.

compared to diamond burs. Similar results were found in the literature using silane after air abrasion and before adhesive application [6,15,26–28]. In addition, other authors [16] presented data evidencing higher bond strength values for RBC repair using air abrasion, hydrofluoric acid, and silane prior to adhesive application. On the other hand, some evidence did not come across statistical differences comparing diamond bur and air abrasion [5,7,29–31]. These evidence stated the need for some kind of roughening method, once using only phosphoric acid as surface treatment for RBC repair, which produces only a cleaning effect, presented poor bond strength results [32]. Conflicting data was presented by only one study [1], stating that higher results in shear bond strength, although not statistically significant, were achieved by using a high-speed coarse diamond bur with water spray for surface treatment compared to air abrasion. The authors reported that the use of a coarse diamond bur creates macro and micro-retentive features on the RBC surface, which contributed to the bond strength improvement noted.

Regarding microtensile bond strength tests, another set of evidence might be found in the literature presenting best results with the use of air abrasion associated with bond systems on RBC repair, regardless of the distance from the device tip to target surface [33–40]. This data is especially true when compared to diamond burs results as surface treatment.

Concerning roughness, some evidence demonstrates that 50 µm aluminum oxide sandblast generates a better surface for RBC bonding repair than fine or course grit diamond burs [34–40]. However, other studies show that they can produce similar bond strength values, but with different roughness patterns [35,41]. SEM and confocal evaluations indicate that sandblasted samples have a greater irregularity and a high number of microcavities, and these morphological findings may be confirmed by profilometric analysis. This pattern of roughness creates the best environment for adhesive system microretention compared to diamond burs [3,39]. High-powered lasers are another alternative described in the literature to improve bond strength in RBC repair, presenting similar microshear [5,42] and microtensile bond strength [37,43] results compared to air abrasion.

There are two different etchants described for the chemical treatment of old RBC. The use of hydrofluoric acid takes into consideration the inorganic filler content exposed by mechanical surface treatment and is expected to partially dissolve the glass-filler particles of RBC, preparing it for the bonding system application [16,39,44]. Phosphoric acid etching technique is already a well-established etching protocol for bonding to enamel and dentin [45], and most repairs include these tissues in their operative substrates [8]. There is no active influence of phosphoric acid on the RBC surface other than cleaning, which is the same outcome achieved by the use of alcohol, acetone, or a pumice prophylaxis [44]. The ease of use of phosphoric acid, the hazard of using it intraorally, and the lack of consensus on hydrofluoric acid etching for RBC repair make phosphoric acid a good and simple alternative to improve bond strength in RBC repair.

Different adhesive systems described in the literature help increase bond strength in RBC repair [6,21,29,46]. It is not the objective of this study to review its role in the interface between the old and the new RBC. Some authors use hydrophobic adhesives once bonding to RBC does not require the hydrophilic and solvent compounds from adhesive primers [26]. This approach might lead to a more stable water-resistant interface, which is favorable considering the higher molecular weight of monomers present in the bond (hydrophobic) portion instead of the low molecular weight in the primer (such as HEMA). Another advantage of using hydrophobic adhesives is the polymer hydrolysis that may occur at the interface when these hydrophilic components are present [35]. Nevertheless, some studies have shown an increase in bond strength when universal adhesives are used. The presence of silane and/or 10-MDP monomer in universal adhesives might explain these results, due to an improvement in chemical interaction between these components and the glass-filler particle in the old RBC [6,21,29,46].

Silanes are molecules presenting a functional chemical group called silanol, which bonds to the glass-filler component of RBC; and an organic functional group able to copolymerize with the methacrylate of the bonding agents [31]. This chemical reaction establishes covalent bonds between the new resin matrix and the glass filler particles of the old RBC [11,42]. Hence, this silane-coated surface becomes more reactive for the methacrylate groups of the repair resin [31]. The use of silane prior to bond adhesive application to the old RBC/new RBC interface is not a well-established evidence-based protocol in RBC repair. Some studies state that it increases the bond strength [6,15,37,47,48] because it enhances the surface wettability of bonding agents, making the old-RBC restoration more reactive and allowing better infiltration into the irregularities produced by the mechanical pretreatment [6,44]. Other studies show no difference when silane is used compared to its absence [7,21,30]. Considering that the cleaning effect of phosphoric acid application on the old composite restoration does not chemically modify the filler content, the use of silane does not effectively improve the repair bond strength [46]. If the dentist chooses to use hydrofluoric acid as a pretreatment, the association of silane might produce significantly higher bond strength results due to the chemical interaction of the silane molecule with the hydrofluoric etched filler content [4,16]. On the other hand, no study had proposed its disadvantage to the repair outcome. Considering that chemical and mechanical treatment of old RBC may expose the filler content, silane may play an important role, even if not a unanimous one, in helping the adhesive adhere to the inorganic matrix of RBC. As it is a simple and cheap procedure, some authors recommend its use as a practice for RBC repair [16,26].

Other authors [37,44,49,50] associated air abrasion, silane, and hydrophobic adhesive to achieve the highest RBC repair bond strength among the protocols tested in their studies. This protocol agrees with other data found in the literature [47,51] about the importance of silane to significantly enhance bond strength in this situation. Nassoohi et al. [10] added phosphoric acid cleaning after micro-abrasion and before silane/adhesive application and found the highest values of bond strength among the groups tested in their experiment. Different studies [8,52,53] stated that one must produce roughness by any means on the surface of old RBC to achieve high bond strength, and only one study [54] did not find variation in bond strength values regarding the use of air abrasion compared to adhesive alone.

Each brand and individual composition of direct RBC materials may influence the outcome of the chosen technique for surface treatment. There were no statistical differences found by the authors in the reviewed literature regarding the influence of the RBC classification on its repair performance [15,20,30].

Concerning the limitations of the study, one may consider that this review evaluated *in vitro* research, with very controlled and standardized operative procedures, which is not always the case in clinical practice. Thus, its outcomes may consider this perspective. Another limitation is that it was not a meta-analysis study, not allowing direct comparison from one study to another.

Overall, there is a great deal of data indicating a repair protocol of mechanical treatment with air abrasion [9,11,20,23,25,34–36,39] followed by a surface cleaning treatment with 37 % phosphoric acid [10], the use of silane [6,15,47], ending with the application of a hydrophobic bonding agent [26] or a universal adhesive system [6,29]. This sequence helps to improve bond strength of new RBC to repair an old RBC restoration. When it is not possible to apply air abrasion, a coarse diamond bur [7,29,30] might be used as a mechanical treatment prior to the described protocol sequence.

Conclusion

Regarding microshear and microtensile bond strength, this literature review shows the advantages of using air abrasion for RBC repair.

CRediT authorship contribution statement

Roberto Zimmer: Conceptualization, Writing – original draft. **Aveline Ribeiro Mantelli:** Conceptualization, Writing – original draft. **Kelin Montagna:** Conceptualization, Writing – original draft. **Eduardo Galia Reston:** Conceptualization, Writing – original draft. **Guilherme Anziliero Arossi:** Conceptualization, Writing – original draft.

Declaration of Competing Interest

There is no competing interest of any kind held by anyone of the authors.

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